Project of Strategic Interest NEXTDATA

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Deliverable NextData D1.4.C

Pollen-based temperature variations over the last 3000 years in the Alpine region

Climate variability over the last 3000 years is here summarized by means of pollen-based July or summer temperature reconstructions obtained at four sites from the Alpine region (Fig. 1). Three longer July temperature series were obtained from high-altitudes sites: Rutor, 2594 m asl; Crotte Basse, 2365 m asl; Armentarga, 2345 m asl, and published respectively in Badino et al. 2018, Pini et al. 2017 and Furlanetto et al. 2018. Only the last 3500 are here considered. Summer temperature estimates (June, July, August, JJA) for the last 3000 years at Lavarone, 1115 m asl, are presented in Vallé et al. (NextData Volume 2, Chapter 11.2*)*. Two pollen-stratigraphical records from different sediment cores from Lavarone lake where used to obtain temperature reconstructions and where published in Arpenti and Filippi (2007) and Filippi et al. (2007).

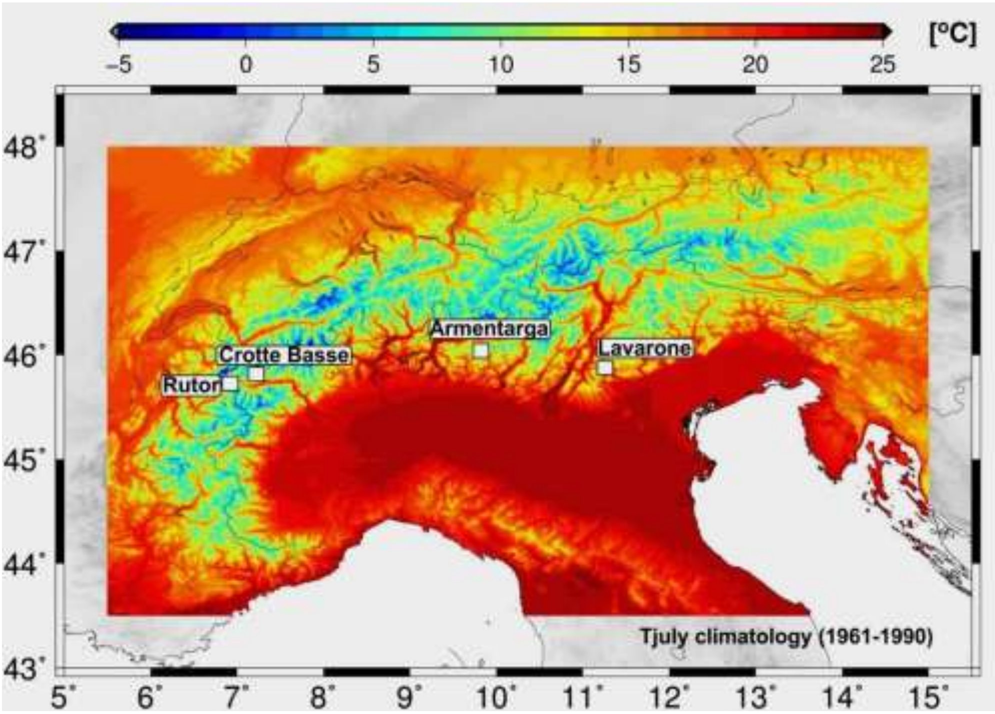

Fig. 1 Locations of the four study sites on a July temperature climatology (1961-1990) map (adapted from Brunetti et al. 2014). Site specific July temperature values are the followings: Rutor- Valter Mire (2594 m asl),

8.2°C, Crotte Basse (2365 m asl), 8.6°C; Armentarga (2345 m a.s.l.), 9.1°C; Lavarone (1115 m asl), 15.7°C. Those values were estimated for the specific sites from Michele Brunetti.

Pollen-climate models (or transfer functions) performances based on different numerical methods (Modern Analogue Technique, Weighted Average (WA) and Weighted Average Partial Least Squares (WA-PLS)) and modern calibration datasets (modern pollen assemblages and associated site-specific climate parameters from the Alpine region) were evaluated using cross-validation process. The root mean square errors of predictions (RMSEP) for the different models developed for the different sites are of about 2°C. Afterwards, these models (or transfer functions) were applied to the four fossil pollen records to estimate past climate parameters. The direct evaluation of the pollen-based reconstructions using instrumental values was possible only for the 200 years reconstruction obtained at Lavarone site (see Deliverable 1.4.B and Vallé et al. 2018).
The absolute temperature values for the last 3500 years cal BP, averaged over 500-years-time windows are presented in Fig. 2. Warmer temperatures are reconstructed for the interval 3500-3000 at Rutor and Crotte Basse sites. Slightly colder temperatures are estimated from 3000 to 2000 years at Rutor and Crotte Basse, while more or less constant temperatures are recorded at Armentarga and Lavarone sites. Part of this interval corresponding to the Iron Age, is marked by glacier expansion in the western Alps (e.g. Badino et al. 2018). Between 2000 and 1500 years cal BP slightly warmer temperatures are estimated for all sites. Slightly colder temperatures are recorded from 1500 years until 500 years cal BP.

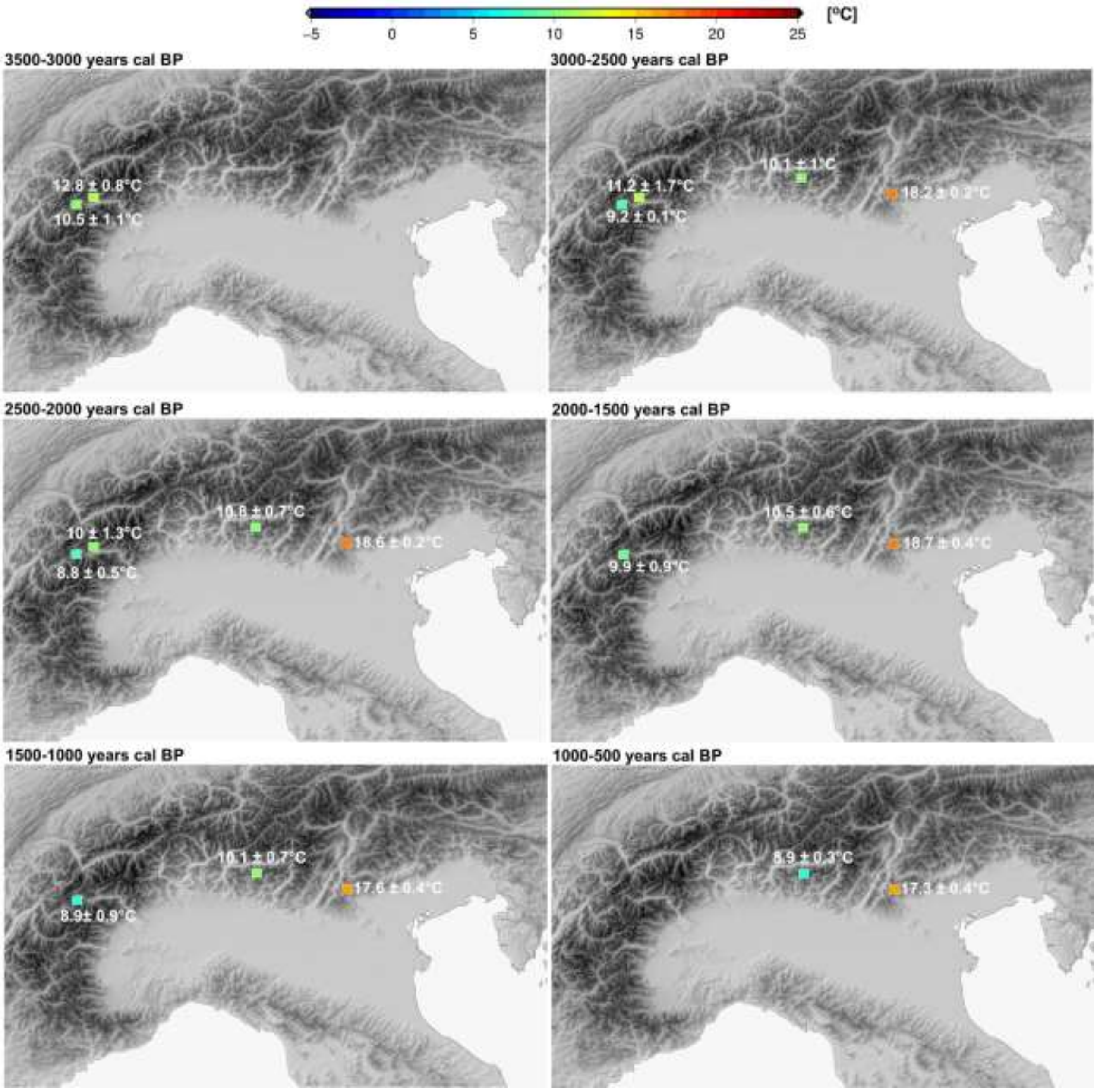

Fig. 2 July temperature (Rutor, Crotte Basse, Armentarga) and summer temperature estimates (Lavarone) in absolute values averaged over 500 years-time windows. The errors represent the standard deviation over the 500-years interval. Reconstructed temperature values were taken from the respective publications: Rutor, Badino et al. 2018; Crotte Basse, Pini et al. 2017; Armentarga, Furlanetto et al. 2018.

The last 500 years are partly recorded only at Armentarga and Lavarone sites. Negative temperature anomalies reconstructed at Lavarone and Armentarga (calculated respect to the entire reconstructed period, not shown here) suggest a temperature cooling corresponding to the Little Ice Age (~AD 1550-1850, e.g. PAGES 2K Consortium, 2013). General colder conditions in this period find agreement in the Continental-scale reconstruction obtained from the PAGES 2k Consortium, although it could not be globally synchronously defined (PAGES 2K Consortium, 2013).

Tree-ring data base for dendroclimatological reconstructions

One of the key factors in modern dendroclimatic analysis is the availability of several tree-ring dataset from different areas of a given region. The possibility of creating a tree-ring network in a given continental region is highly enhanced by the possibility of retrieving data from accessible and open access data base.

Nowadays, the largest data base available is the International Tree-Ring Data Base (ITRDB), a public database managed by the NCEI's Paleoclimatology Team and the World Data Center for Paleoclimatology under the NOAA, the National Oceanic and Atmospheric Administration of the USA (https://www.ncdc.noaa.gov/data-access/paleoclimatology-data/datasets/tree-ring). It contains over 10,000 datasets from more than 4,000 sites over 6 continents, providing series of ring widths, tree-ring maximum and minimum density, tree-ring stable isotopes, as well as tree-ring based reconstructions.
The Italian sites of the ITRDB have been recently analysed within the NEXDATA project and the available series processed in the view of a dendroclimatic analysis. These sites, together with sites within 50 km from the Italian boundary and with the sites collected from the Italian 'dendro community', have been included in the NEXTDATA online database (http://geomatic.disat.unimib.it/dendro): overall, 391 sites are currently included (Fig. 3). The Italian dendro community has positively responded to the call of Università degli Studi di Milano-Bicocca, and in particular the following participants, actively sent information on available dendrochronological datasets form several sites: Università della Campania - Dipartimento di Scienze e Tecnologie Ambientali, Biologiche e Farmaceutiche (DiSTABiF); Universita degli Studi del Molise - Dipartimento Bioscienze e Territorio; Università degli Studi della Basilicata - Dipartimento di Scienze dei Sistemi Colturali, Forestali e dell'Ambiente; Università degli Studi di Pisa - Dipartimento di Scienze della Terra; Università degli Studi di Milano - Dipartimento di Scienze della Terra; Università degli Studi di Pavia - Dipartimento di Ecologia del Territorio; Università degli Studi di Padova -Dipartimento Territorio e Sistemi Agro-Forestali; Museo Civico di Rovereto - Laboratorio di Dendrocronologia.

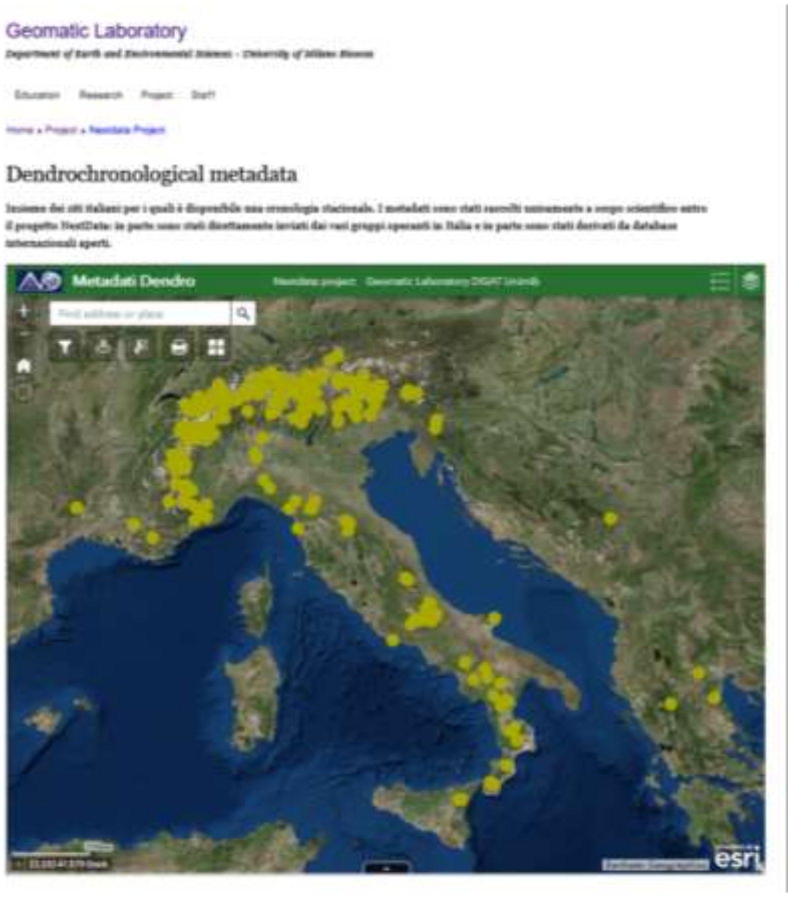

Fig. 3 The tree-ring database set up for the NEXTDATA project, settled at the Università degli Studi di Milano-Bicocca; it comprises dendrochronological sites from Italy and nearby countries.

The availability of data to single research groups is not anymore enough for developing robust dendroclimatic networks. We think that the opportunity given by the open access database to participate to international researches, is a challenge and an opportunity to be taken also by the

Italian dendro community in order to provide data from its climate-sensitive hot spots, the Mediterranean and southern side of the entire Alpine arch.

Dendroclimatology for the Alps and the Mediterranean region

Dendroclimatology is the study of tree rings focused in providing insights from the past climate conditions over regions, going back in time well before the first instrumental records. By calibrating models usually in the most recent period covered also by climatic data, and then applying transfer function to the tree-ring chronologies it is possible to estimate past temperature or past precipitation variability, but also more other climatic parameters like e.g. air humidity, cloud cover or more complex climatic indices like the NAO. However, reconstructing the past climate is not the only objective of dendroclimatology: one of the main objective of the climate reconstructions is to provide insights on the predictability of future climate and climate patterns, especially under the ongoing marked climatic and environmental changes.

For the European Alps, at least two millennium-long reconstructions exist: one is based on larch from Switzerland and pine from Austria (Büntgen et al., 2005), the other also includes sites form western (French) and eastern (Italian) Alps (Corona et al., 2010). Both reconstructions report unprecedented summer temperatures in the recent decades of their respective observations, confirming the ability of ring-widths from mountain sites to follow the recent atmosphere warming trends. Another temperature reconstruction is based on tree-ring maximum latewood density (MXD) from Swiss sites of larch and spans over 1250 years (Büntgen et al, 2006). Like the other two reconstructions, it reports extreme years for the recent period, severe temperature conditions occurring during the little Ice Age and its coolest peak during 1810s, and warmer conditions than previous and following periods during the medieval times. For the Italian Alps, central sector, a first summer temperature reconstruction based on larch chronologies has been performed on the Adamello-Presanella Group (Coppola et al., 2013), dating back to 1610 and another reconstruction based on a multispecies approach was performed in the same region, comprising also sites from northern mountain groups also from Switzerland and Austria (Leonelli et al., 2016), dating back to 1560s (Fig. 4).

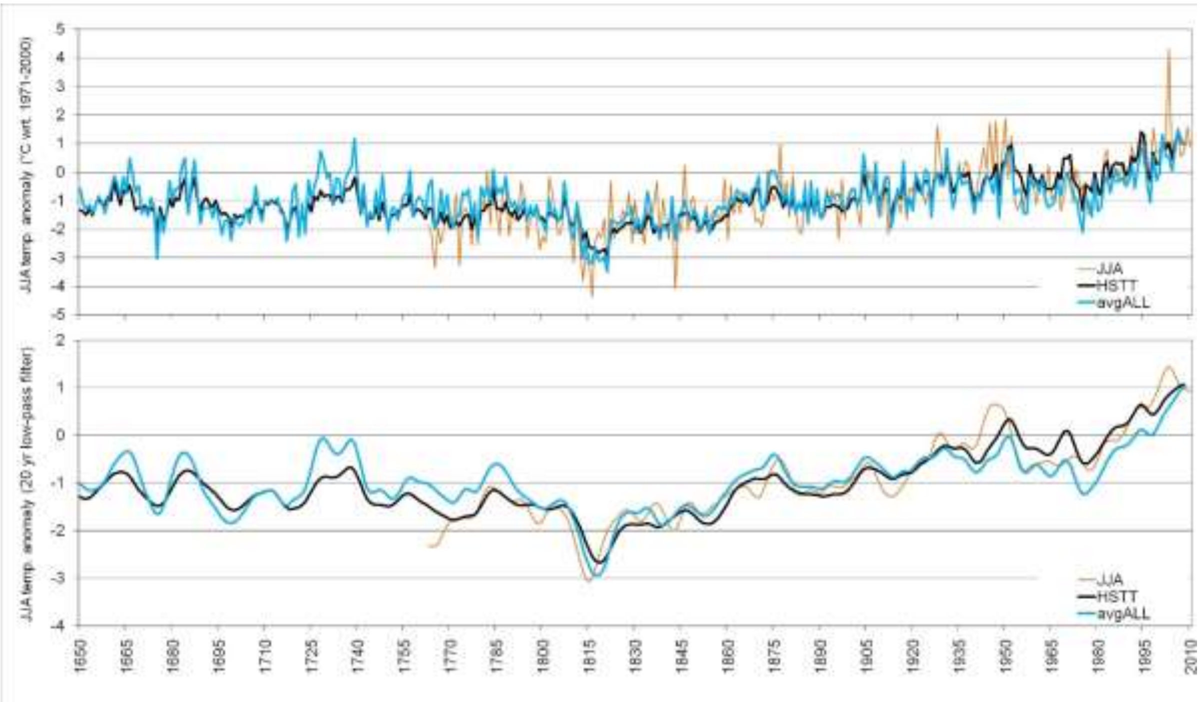

Fig. 4 Reconstruction of JJA temperature anomalies based on the HSTT and avgALL chronologies based on 42 tree-ring chronologies from high-altitude forest sites in a region of the central European Alps comprising five highly glacierized mountain groups: the Silvretta Group (Switzerland), the Ötztaler-Venoste Alps (Austria, Italy), the Bernina Group (Switzerland, Italy), the Ortles-Cevedale Group (Italy) and the Adamello-Presanella Group (Italy). The Gaussian 20-yr. low-pass filtered reconstructions are also reported.

Following an innovative tree-based approach, a multispecies dendroclimatic network has been used in the central region of the Alps for reconstructing past summer temperature. The reconstruction includes *L. decidua, P. cembra* and *P. abies*, and is based on a chronology built with an iterative process (the HSTT). The resulting reconstruction is not fully independent from the climatic record used for the model calibration, but it holds the strongest climatic signals and has allowed the reconstruction of summer temperature for periods prior to the instrumental record over the last ~450 years.

Temperature reconstructions in the Mediterranean region are less frequent than the reconstruction of precipitation or drought indices, however some efforts have been performed, mainly including sites from mountain environments (under sub-Mediterranean climatic conditions). Even if these reconstructions have temperature as major target, in this environment temperature and precipitation are frequently negatively correlated, especially during summer, and trees respond to high/low temperature and lack/availability of soil moisture. Therefore, the resulting temperature reconstructions often hold precipitation signals. Over a wide northeastern Mediterranean-Balkan region comprising Italy, part of the Italian Alps, the Balkans, Greece and central Romania and Bulgaria, a first late-summer temperature reconstruction was performed using ring-width and MXD data (Trouet, 2014). Based on a tree-based approach similar to the one applied in the Alps, a better performing reconstruction of late-summer temperature has been performed for the Italian Peninsula using only MXD chronologies from the Apennine (Leonelli et al., 2017a; Fig. 5). The resulting reconstruction dated back to 1700s and showed very high coherence with the temperature variability over a wider region comprising Sardinia, Sicily, northern Africa and the Balkans; moreover, it showed also a dipole in precipitation patterns between the northern Balkans and a region comprising the Ireland, Scotland and the southern Scandinavia.

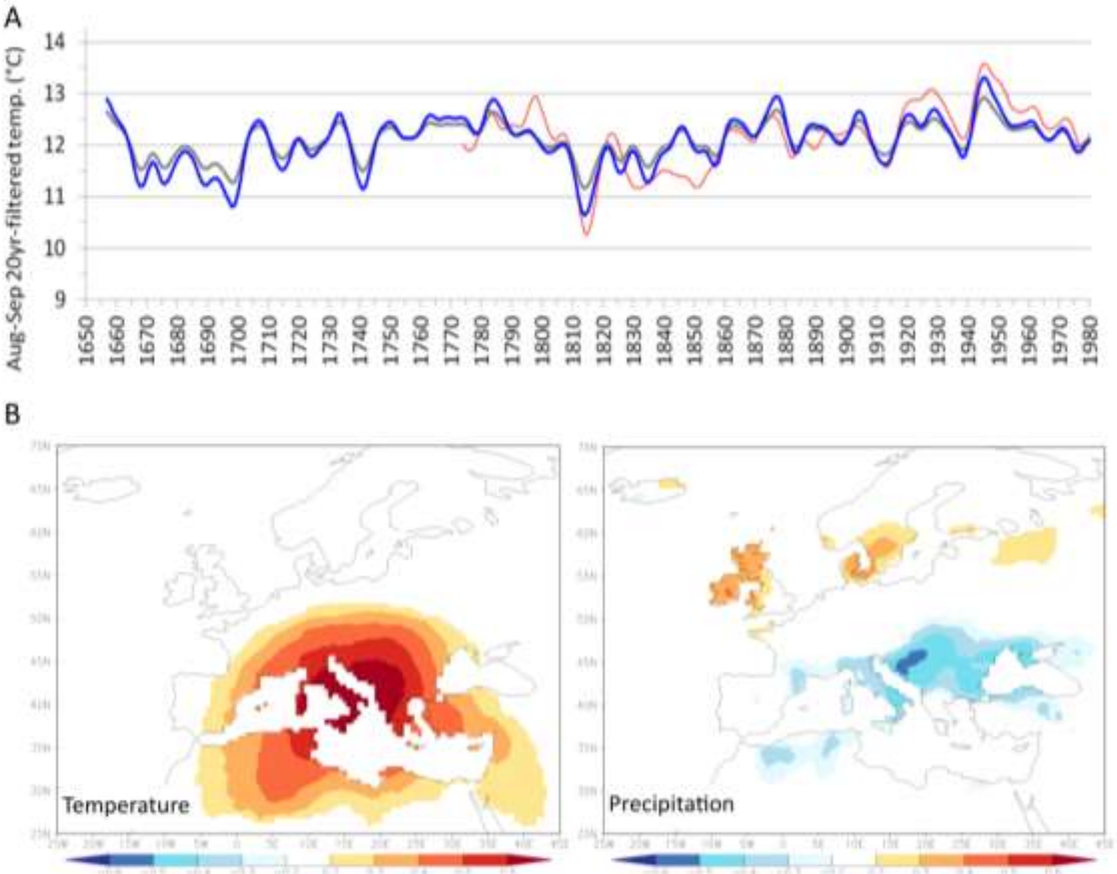

Fig. 5A Reconstruction of late summer temperature using the conifer MXD chronology from the Italian

Peninsula, low-pass-filtered with a 20-year Gaussian smoother for the two reconstructions based on scaling and regression. Prior to 1714 the conifer MXD chronology shows an EPS < 0.79; EPS > 0.85 from 1734 (EPS, expressed population signal, an index linked to signal stability; Wigley et al., 1984; Briffa and Jones, 1990).
5B Spatial correlation pattern of the reconstructed late summer temperature using the MXD chronology versus the 0.5◦ grid CRU TS 4.0 (Harris et al., 2014) August–September mean temperature (left) and mean precipitation (right), over the period of 1901–1980. (from Leonelli et al., 2017a, modified).

Isotopic signatures of winter snow in tree-ring data

Tree-ring stable isotopes can currently be considered the last frontier in dendroclimatology, for the very high climate sensitivity showed in different and also non-climatically extreme sites. The $\delta^{13}C$ variability in the stem cellulose is driven primarily by tree photosynthetic capacity and stomatal conductance The analysis of $\delta^{18}O$ in glacial environments has the advantage to work in presence of shallow soils, where water fractionation through the soil profile can considered absent if we exclude a possible first enrichment given by surface evaporative processes (usually not so marked). As a consequence, the isotopic signature in trees directly reflects the isotopic signature of the source waters, that could be either be linked to precipitation signals or to glacier meltwater signals if the trees are growing in the vicinity of the glacier stream. Based on these assumptions past glacier runoff events have been detected by means of the tree-ring $\delta^{18}O$ (Leonelli et al., 2014). A study recently conducted in the valley of the Forni Glacier (in upper Valtellina, Italy) has demonstrated that the cellulose $\delta^{18}O$ of trees growing in the valley bottom towards the valley slope are influenced by the $\delta^{18}O$ of winter snow and summer precipitation (Leonelli et al. 2017b), with the $\delta^{18}O$ chronology explaining up to 34% of the winter precipitation $\delta^{18}O$ variability over the period of analysis (1980-2010).

Overall, the tree-ring stable isotopes are proving to be very sensitive climate proxies, however the great variety of signals recorded is still not fully assessed, mainly depending of the species sensitivity, on the soil characteristics and on the environmental settings, all factors influencing the tree's physiological conditions. As demonstrated, the use of tree-ring stable isotopes in glacial environments may provide useful information on spatio-temporal patterns of glacier meltwater availability and distribution, as well as of past winter precipitation $\delta^{18}O$.

A combination of tree-rings and pollen-based summer temperature reconstruction for the eastern Alps

A first combination of pollen and tree rings summer temperature reconstruction for the last 3000 years, was performed in the central sector of the Italian Alps (area in red-box in Fig. 6, see also Deliverable D1.4.A).

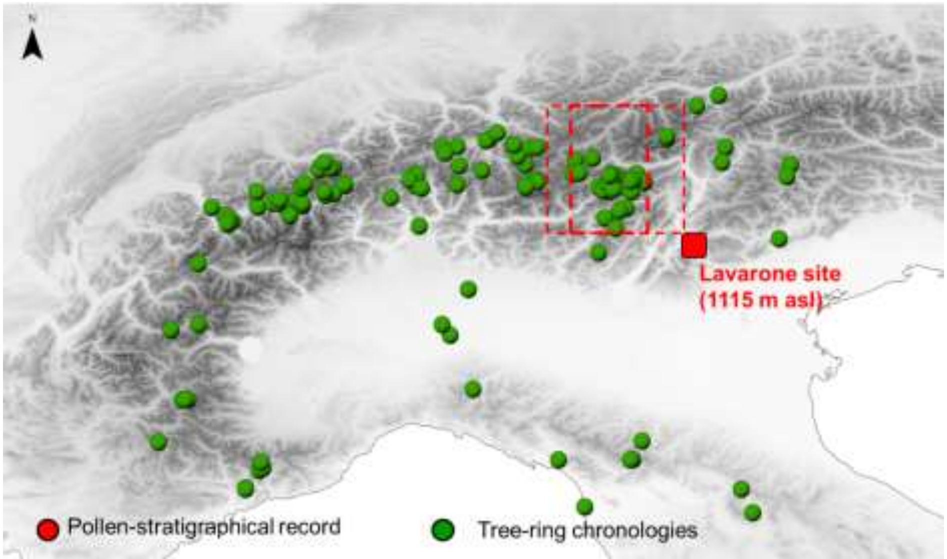

Fig. 6 Available tree-ring chronologies and Lavarone lake (red filled square). In red, the study region where the test was conducted.

Tree rings and pollen-stratigraphical records typically cover different time lengths and show different time resolutions. The assessment of the relationships between the variability of these two proxy records over a selected common period is shown in Deliverable **D1.4.A.**
Here we present the “joint” reconstruction of the summer temperature anomalies (respect to 1971-2000; Fig. 7).

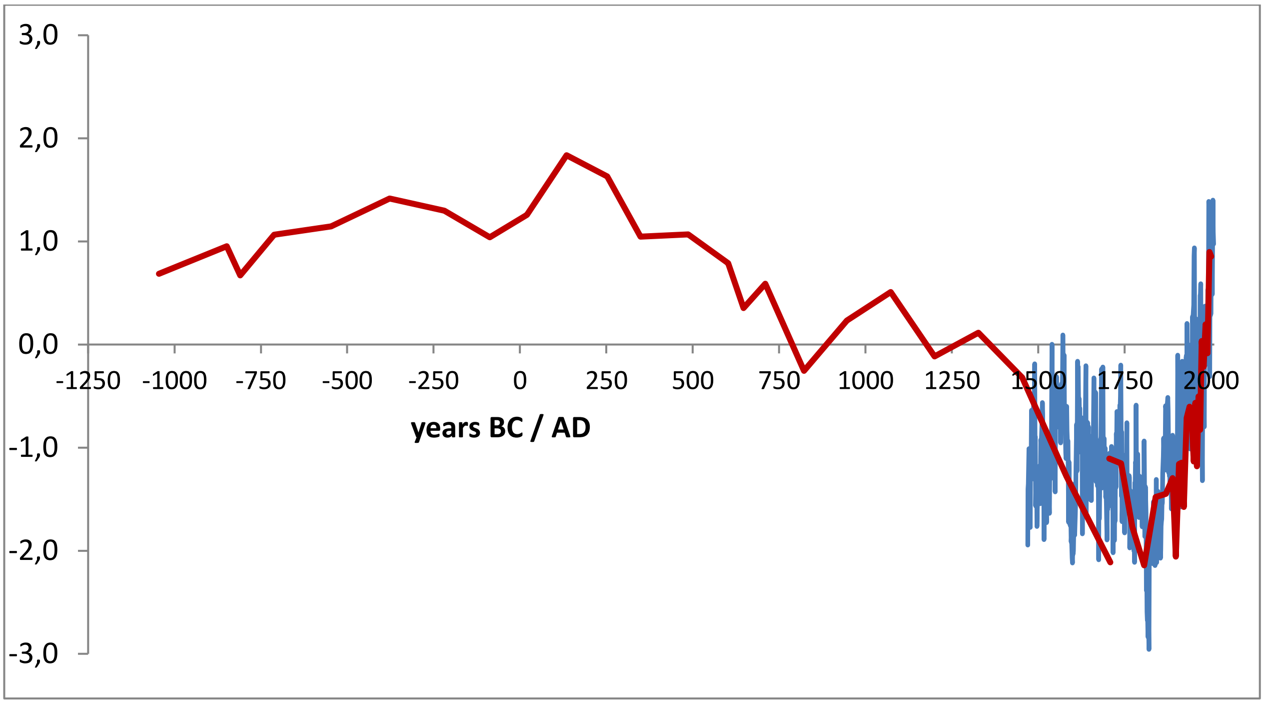

Fig. 7 Summer temperature anomalies (with respect to the 1971-2000 mean) reconstructed from tree rings chronologies (blue curve) and fossil pollen data (red curves). The tree ring anomaly reconstruction was obtained with a HSTT model for the interval 1500-2000 years AD (Leonelli et al. 2016). The pollen-based reconstructions were obtained by means of pollen-climate models (or WA, WA-PLS transfer functions) (from Vallé et al. 2018, see also Deliverable D1.4.B) from two different pollen records from Lavarone lake (Filippi et al. 2007, Arpenti and Filippi, 2007). The error associated to the pollen reconstructions in absolute values is the root mean square error of predictions, RMSEP=2.4°C.

References

Arpenti E., Filippi M.L. (2007). Evoluzione della vegeta-zione nei pressi del Lago di Lavarone (TN) negli ultimi 2200 anni. Studi Trent. Sci. Nat., Acta Geol., 82, 317-324.

Badino F., Ravazzi C., Vallé F., Pini R., Aceti A., Brunetti M., Champvillair E., Maggi V., Maspero F., Perego R. & Orombelli G. (2018). 8800 years of high-altitude vegetation and climate history at the Rutor Glacier foreland, Italian Alps. Evidence of Middle Holocene timberline rise and glacier contraction. Quaternary Science Reviews, 185, 41-68.

Briffa, K. R. and Jones, P. D. (1990). Basic chronology statistics and assessment, in: Methods of Dendrochronology, Applications in the Environmental Sciences, edited by: Cook, E. R. and Kairiukstis, L. A., 137–152, Kluwer, Dordrecht, the Netherlands.

Büntgen, U., Esper, J., Frank, D.C., Nicolussi, K., Schmidhalter, M., (2005). A 1052-year tree-ring proxy for Alpine summer temperatures. Climate Dynamics 25, 141–153. https://doi.org/10.1007/s00382-005-0028-1.

Büntgen, U., Frank, D. C., Nievergelt, D., and Esper, J. (2006). Summer temperature variations in the European Alps, AD 755-2004, J. Climate, 19, 5606–5623.

Coppola, A., Leonelli, G., Salvatore, M.C., Pelfini, M., Baroni, C., (2013). Tree-ring–based summer mean temperature variations in the Adamello–Presanella Group (Italian Central Alps), 1610–2008 AD. Climate of the Past 9, 211–221. https://doi.org/10.5194/cp-9-211-2013.

Corona, C., Guiot, J., Edouard, J.L., Chalié, F., Büntgen, U., Nola, P., Urbinati, C., (2010). Millennium-long summer temperature variations in the European Alps as reconstructed from tree rings. Climate of the Past 6, 379–400. https://doi.org/10.5194/cp-6-379-2010.

Filippi M.L., Heiri O., Arpenti E., Angeli N., Bortolotti M., Lotter A. & Van Der Borg K. (2007). Evoluzione paleoambientale dal Tardoglaciale a oggi ricostruita attraverso lo studio dei sedimenti del Lago di Lavarone (Altopiano di Folgaria e Lavarone, Trentino). *Studi Trent. Sci. Nat*. Acta Geologica, 82, 279-298.

Furlanetto G., Ravazzi C., Pini R., Vallé F., Brunetti M., Comolli R., Novellino M.D., Garozzo L. & Maggi V. (2018). Holocene vegetation history and quantitative climate reconstructions in a high-altitude oceanic district of the Italian Alps. Evidence for a middle to late Holocene precipitation increase. Quaternary Science Reviews, 200, 210-236.

Harris, I., Jones, P. D., Osborn, T. J. and Lister, D. H. (2014). Updated high-resolution grids of monthly climatic observations – the CRU TS3.10 Dataset, Int. J. Climatol., 34, 623–642, https://doi.org/10.1002/joc.3711, 2014.

Leonelli, G., Pelfini, M., Battipaglia, G., Saurer, M., Siegwolf, R.T.W., Cherubini, P., (2014). First detection of glacial meltwater signature in tree-ring δ18O: Reconstructing past major glacier runoff events at Lago Verde (Miage Glacier, Italy): Glacial meltwater signature in tree-ring δ 18 O, Lago Verde, Italy. Boreas 43, 600–607. https://doi.org/10.1111/bor.12055.

Leonelli, G., Coppola, A., Baroni, C., Salvatore, M.C., Maugeri, M., Brunetti, M., Pelfini, M., (2016). Multispecies dendroclimatic reconstructions of summer temperature in the European Alps enhanced by trees highly sensitive to temperature. Climatic Change 137, 275–291. https://doi.org/10.1007/s10584-016-1658-5.

Leonelli, G., Coppola, A., Salvatore, M.C., Baroni, C., Battipaglia, G., Gentilesca, T., Ripullone, F., Borghetti, M., Conte, E., Tognetti, R., Marchetti, M., Lombardi, F., Brunetti, M., Maugeri, M., Pelfini, M., Cherubini, P., Provenzale, A., Maggi, V., (2017a). Climate signals in a multispecies tree-ring network from central and southern Italy and reconstruction of the late summer temperatures since the early 1700s. Climate of the Past 13, 1451–1471, https://doi.org/10.5194/cp-13-1451-2017.

Leonelli, G., Battipaglia, G., Cherubini, P., Saurer, M., Siegwolf, R.T.W., Maugeri, M., Stenni, B., Fusco, S., Maggi, V., Pelfini, M., (2017b). *Larix decidua* $\delta^{18}O$ tree-ring cellulose mainly reflects the isotopic signature of winter snow in a high-altitude glacial valley of the European Alps. Science of The Total Environment 579, 230–237. https://doi.org/10.1016/j.scitotenv.2016.11.129.

PAGES 2K Consortium, (2013). Continental-scale temperature variability during the past two millennia. Nature Geoscience volume 6, pages 339–346.

Pini, R., Ravazzi, C., Raiteri, L., Guerreschi, A., Castellano, L., Comolli, R., (2017). From pristine forests to high-altitude pastures: an ecological approach to prehistoric human impact on vegetation and landscapes in the western Italian Alps. Journal of Ecology, 105, 1580-1597.

Trouet, V. (2014). A tree-ring based late summer temperature reconstruction (AD 1675–1980) for the northeastern Mediterranean. Radiocarbon, 56(4), S69–S78, doi:10.2458/azu_rc.56.18323.

Vallé F., Brunetti M., Pini R., Maggi V., Ravazzi C. (2018). Alpine and Mediterranean Quaternary, Vol. 31, 165 – 168.

Vallé F., Furlanetto G., Pini R., Brunetti M., Maggi V., Ravazzi C., submitted. Reconstructing the last 3000 years climate change in N-Italy from fossil pollen archives. Chapter 11.2 in NextData Volume 2*.*

Wigley, T. M. L., Briffa, K. R., and Jones, P. D. (1984). On the average value of correlated time series, with applications in dendroclimatology and hydrometeorology, J. Clim. Appl. Meteorol., 23, 201–213, 1984.